

AASHTOWare BrD/BrR 6.8

Prestressed Concrete Structure Tutorial

PS5 – Void Prestressed Box Beam Example

BrR and BrD Training

PS5 – Void Prestressed Box Beam Example

From the Bridge Explorer create a new bridge and enter the following description data:

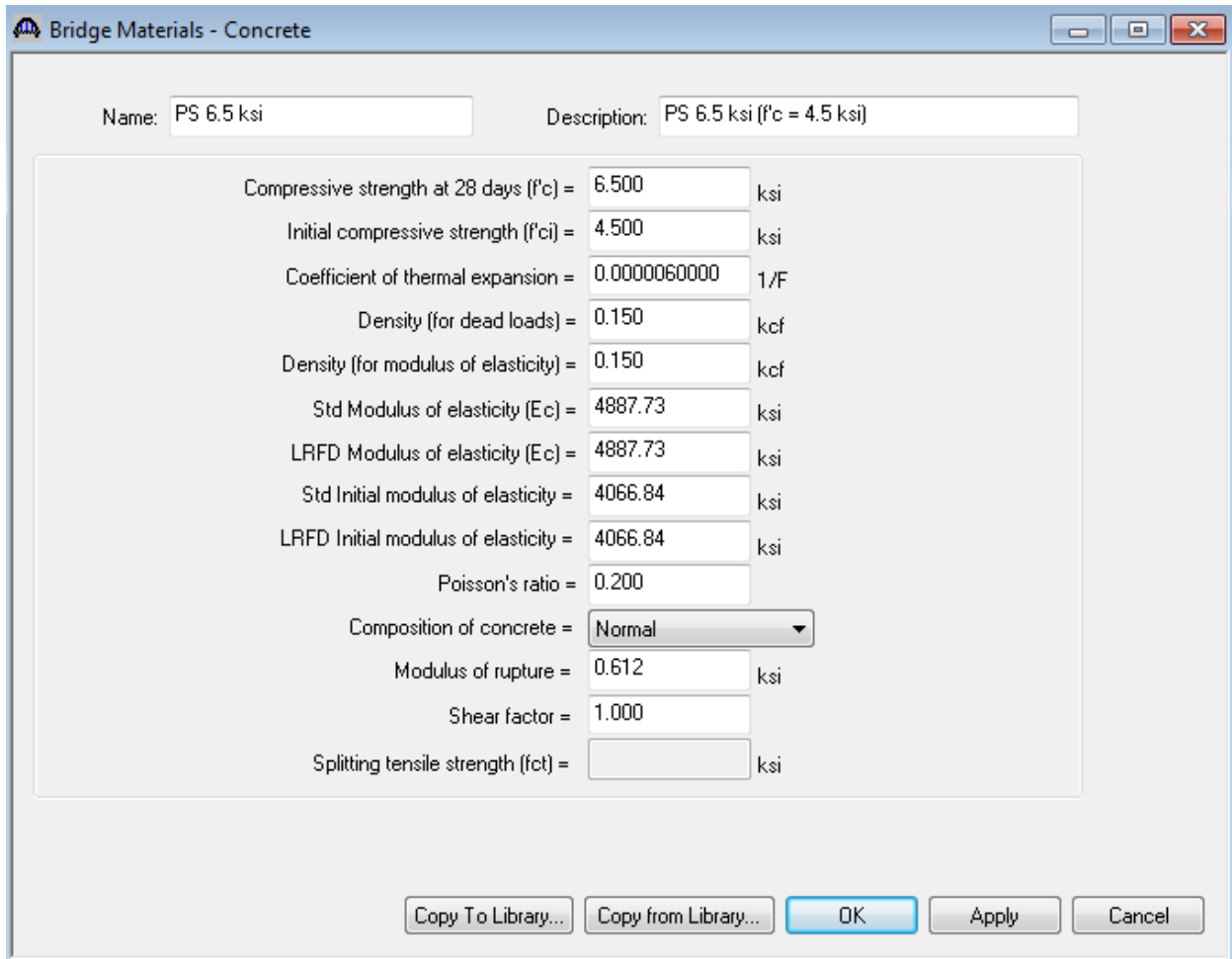
The screenshot shows a software window titled "PS5TrainingBridge" with a standard Windows-style title bar (minimize, maximize, close buttons). The window contains a form for entering bridge data. At the top, there are two text boxes: "Bridge ID:" with the value "PS5TrainingBridge" and "NBI Structure ID (8):" with the value "PS5TrainingBrid". To the right of these are three checkboxes: "Template" (unchecked), "Superstructures" (checked), "Bridge Completely Defined" (unchecked), and "Culverts" (unchecked). Below this is a tabbed interface with the "Description" tab selected. The "Description" tab contains several fields: "Name:" with the value "Void PS Box Example", "Year Built:" (empty), "Description:" (a large empty text area), "Location:" (empty), "Length:" (empty) followed by "ft", "Facility Carried (7):" (empty), "Route Number:" with the value "-1", "Feat. Intersected (6):" (empty), "Mi. Post:" (empty), and "Default Units:" with a dropdown menu set to "US Customary". At the bottom of the window, there is a button labeled "AASHTOWare Association..." and three checkboxes: "BrR" (checked), "BrD" (checked), and "BrM" (unchecked). On the far right, there are three buttons: "OK", "Apply", and "Cancel".

Close the window by clicking Ok. This saves the data to memory and closes the window.

PS5 – Void Prestressed Box Beam Example

To enter the materials to be used by members of the bridge, click on the **+** to expand the tree for Materials. To add a new concrete material click on Concrete in the tree and select File/New from the menu (or right mouse click on Concrete and select New).

Add the concrete material “PS 6.5 ksi” by entering the data as follows. Click Ok to save the data to memory and close the window. This concrete will be used for the beam concrete in this example.



The screenshot shows a dialog box titled "Bridge Materials - Concrete". It contains the following fields and values:

Property	Value	Unit
Name	PS 6.5 ksi	
Description	PS 6.5 ksi (f'c = 4.5 ksi)	
Compressive strength at 28 days (f'c)	6.500	ksi
Initial compressive strength (f'ci)	4.500	ksi
Coefficient of thermal expansion	0.0000060000	1/F
Density (for dead loads)	0.150	kcf
Density (for modulus of elasticity)	0.150	kcf
Std Modulus of elasticity (Ec)	4887.73	ksi
LRFD Modulus of elasticity (Ec)	4887.73	ksi
Std Initial modulus of elasticity	4066.84	ksi
LRFD Initial modulus of elasticity	4066.84	ksi
Poisson's ratio	0.200	
Composition of concrete	Normal	
Modulus of rupture	0.612	ksi
Shear factor	1.000	
Splitting tensile strength (fct)		ksi

At the bottom of the dialog box, there are five buttons: "Copy To Library...", "Copy from Library...", "OK", "Apply", and "Cancel".

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Add a concrete material for the deck by entering the following data. The window will look like the one shown below:

The image shows a software dialog box titled "Bridge Materials - Concrete". It contains several input fields for defining a concrete material. The "Name" field is filled with "Deck Concrete". The "Description" field is empty. Below these are various material properties, each with a numerical input field and a unit label. At the bottom, there are five buttons: "Copy To Library...", "Copy from Library...", "OK", "Apply", and "Cancel".

Property	Value	Unit
Name	Deck Concrete	
Description		
Compressive strength at 28 days (f'_c)	4.500	ksi
Initial compressive strength (f'_{ci})		ksi
Coefficient of thermal expansion	0.0000060000	1/F
Density (for dead loads)	0.150	kcf
Density (for modulus of elasticity)	0.145	kcf
Std Modulus of elasticity (E_c)	3865.20	ksi
LRFD Modulus of elasticity (E_c)	3865.20	ksi
Std Initial modulus of elasticity	0.00	ksi
LRFD Initial modulus of elasticity	0.00	ksi
Poisson's ratio	0.200	
Composition of concrete	Normal	
Modulus of rupture	0.509	ksi
Shear factor	1.000	
Splitting tensile strength (f_{ct})		ksi

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Add a reinforcement material using the Copy from Library techniques. The windows will look like the one shown below:

Bridge Materials - Reinforcing Steel

Name: Description:

Material Properties

Specified yield strength (F_y) = ksi

Modulus of elasticity (E_s) = ksi

Ultimate strength (F_u) = ksi

Type

Plain
 Epoxy
 Galvanized
 Other

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Add a prestress strand using the Copy from Library techniques. The windows will look like the one shown below:

Bridge Materials - PS Strand

Name: 1/2" (7W-270) LR Description: Low relaxation 1/2"/Seven Wire/fpu = 270

Strand diameter = 0.5000 in

Strand area = 0.153 in²

Strand type = Low Relaxation

Ultimate tensile strength (Fu) = 270.000 ksi

Yield strength (Fy) = 243.000 ksi

Modulus of elasticity (E) = 28500.00 ksi

Transfer length (Std) = 25.0000 in

Transfer length (LRFD) = 30.0000 in

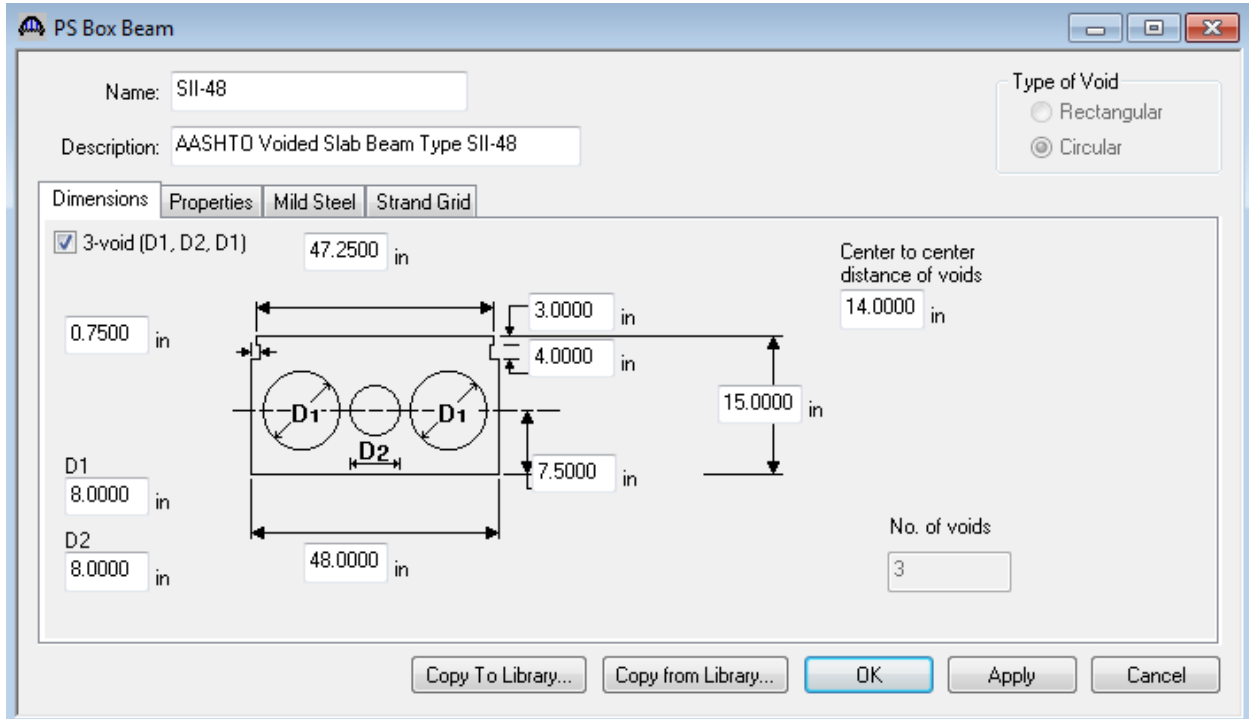
Unit load per length = 0.520 lb/ft

Epoxy coated

Copy To Library... Copy from Library... OK Apply Cancel

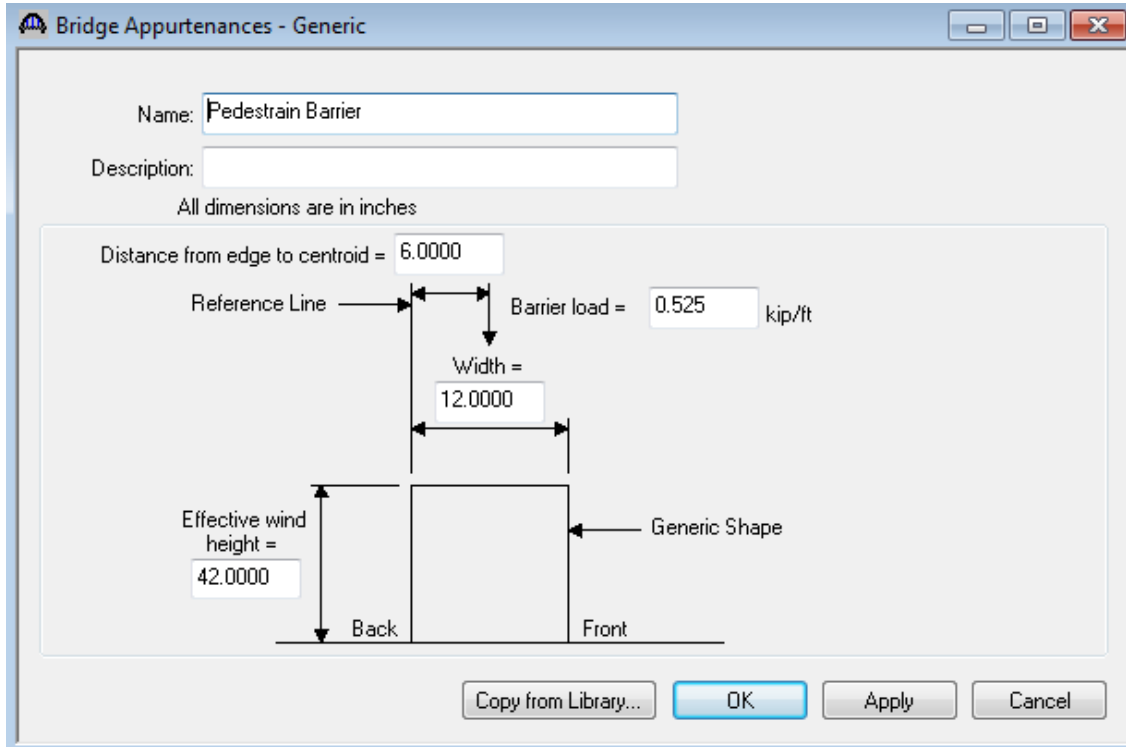
PS5 – Void Prestressed Box Beam Example

To enter a prestress beam shape to be used in this bridge expand the tree item labeled Beam Shapes. Click on Box Beams in the tree and select File/New from the menu (or double click on Box Beams in the tree). Select the Void Type as Circular and click on the Copy from Library button. Select SII-48 and click Ok. The beam properties are copied to the Box Beam window as shown below.



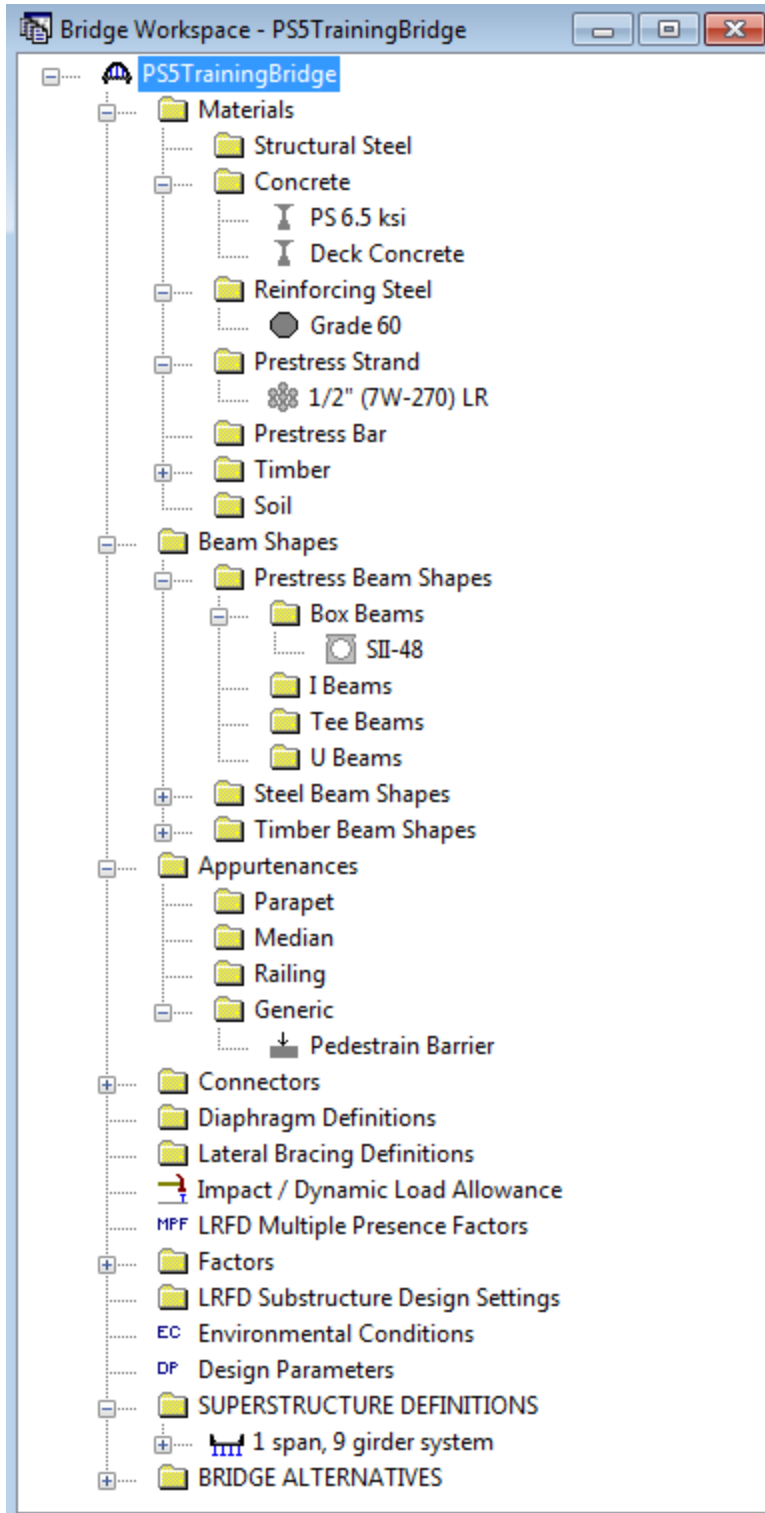
PS5 – Void Prestressed Box Beam Example

To enter the appurtenances to be used within the bridge expand the tree branch labeled Appurtenances. This bridge has a concrete pedestrian railing. Define a Generic appurtenance to model the concrete railing. The completed window is shown below:



PS5 – Void Prestressed Box Beam Example

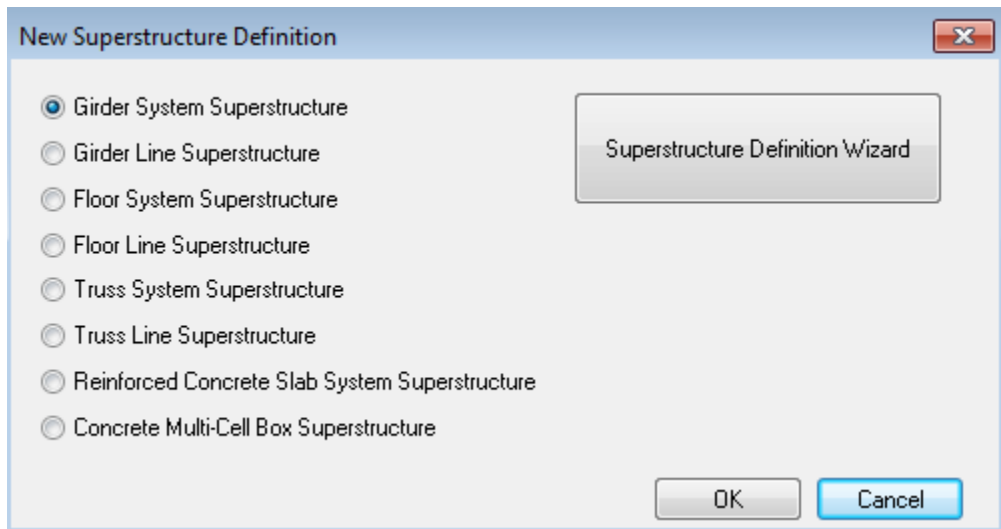
The Bridge Workspace is shown below:



PS5 – Void Prestressed Box Beam Example

The default impact factors, standard LRFD and LFD factors will be used so we will skip to Structure Definition. Bridge Alternatives will be added after we enter the Structure Definition.

Double click on SUPERSTRUCTURE DEFINITIONS (or click on SUPERSTRUCTURE DEFINITIONS and select File/New from the menu or right mouse click on SUPERSTRUCTURE DEFINITIONS and select New from the popup menu) to create a new structure definition. The dialog shown below will appear.



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Select Girder System and the Structure Definition window will open. Enter the appropriate data as shown below:

Girder System Superstructure Definition

Definition Analysis Specs Engine

Name: 1 span, 9 girder system

Description:

Default Units: US Customary

Number of spans: 1

Number of girders: 9

Enter Span Lengths Along the Reference Line:

Span	Length (ft)
1	52.00

Frame Structure Simplified Definition:

Deck type: Concrete

For PS only

Average humidity: 70.000 %

Member Alt. Types

- Steel
- P/S
- R/C
- Timber

Horizontal Curvature Along Reference Line

Horizontal curvature

Superstructure Alignment

- Curved
- Tangent, curved, tangent
- Tangent, curved
- Curved, tangent

Distance from PC to first support line: _____ ft

Start tangent length: _____ ft

Radius: _____ ft

Direction: Left

End tangent length: _____ ft

Distance from last support line to PT: _____ ft

Design speed: _____ mph

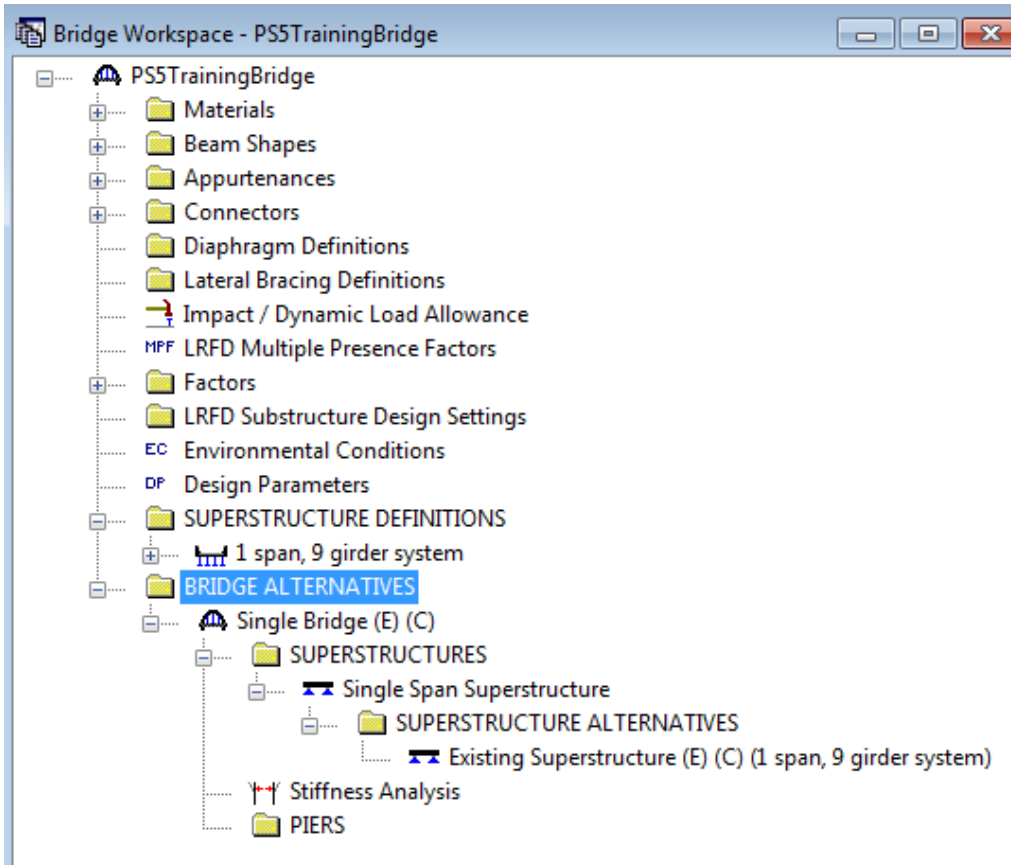
Superelevation: _____ %

OK Apply Cancel

Click on Ok to save the data to memory and close the window.

PS5 – Void Prestressed Box Beam Example

We now go back to the Bridge Alternatives and create a new Bridge Alternative, a new Superstructure, and a new Superstructure Alternative. The partially expanded Bridge Workspace tree is shown below:



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Click Load Case Description to define the dead load cases. The completed Load Case Description window is shown below.

Load Case Name	Description	Stage	Type	Time* (Days)
DL1 DC	Sidewalks	Non-composite (Stage 1)	D,DC	
DL2 DC	Barriers	Composite (long term) (Stage 2)	D,DC	

*Prestressed members only

Add Default Load Case Descriptions

New Duplicate Delete

OK Apply Cancel

PS5 – Void Prestressed Box Beam Example

Double-click on Framing Plan Detail to describe the framing plan. Enter the appropriate data as shown below.

Structure Framing Plan Details

Number of spans = 1 Number of girders = 9

Layout Diaphragms

Girder Spacing Orientation

- Perpendicular to girder
- Along support

Support	Skew (Degrees)
1	0.0000
2	0.0000

Girder Bay	Girder Spacing (ft)	
	Start of Girder	End of Girder
1	4.00	4.00
2	4.00	4.00
3	4.00	4.00
4	4.00	4.00
5	4.00	4.00
6	4.00	4.00
7	4.00	4.00
8	4.00	4.00

OK Apply Cancel

This structure does not have any external diaphragms since it is an adjacent box beam system. Click Ok to save the data to memory and close the window.

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Next define the structure typical section by double-clicking on Structure Typical Section in the Bridge Workspace tree. Input the data describing the typical section as shown below.

Structure Typical Section

Distance from left edge of deck to superstructure definition ref. line

Distance from right edge of deck to superstructure definition ref. line

Deck thickness

Superstructure Definition Reference Line

Left overhang

Right overhang

Deck | Deck (Cont'd) | Parapet | Median | Railing | Generic | Sidewalk | Lane Position | Striped Lanes | Wearing Surface

Superstructure definition reference line is within the bridge deck.

	Start	End
Distance from left edge of deck to superstructure definition reference line =	18.00 ft	18.00 ft
Distance from right edge of deck to superstructure definition reference line =	18.00 ft	18.00 ft
Left overhang =	2.00 ft	2.00 ft
Computed right overhang =	2.00 ft	2.00 ft

OK Apply Cancel

PS5 – Void Prestressed Box Beam Example

The Deck (cont'd) tab is used to enter information about the deck concrete and thickness. The material to be used for the deck concrete is selected from the list of bridge materials described above.

Structure Typical Section

Distance from left edge of deck to superstructure definition ref. line

Distance from right edge of deck to superstructure definition ref. line

Deck thickness

Superstructure Definition Reference Line

Left overhang

Right overhang

Deck Deck (Cont'd) Parapet Median Railing Generic Sidewalk Lane Position Striped Lanes Wearing Surface

Deck concrete: Deck Concrete

Total deck thickness: 6.0000 in

Load case: Engine Assigned

Deck crack control parameter: 130.000 kip/in

Sustained modular ratio factor: 2.000

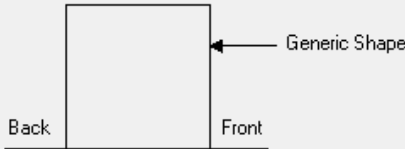
Deck exposure factor:

OK Apply Cancel

PS5 – Void Prestressed Box Beam Example

Add the concrete railings and sidewalk as follows:

Structure Typical Section



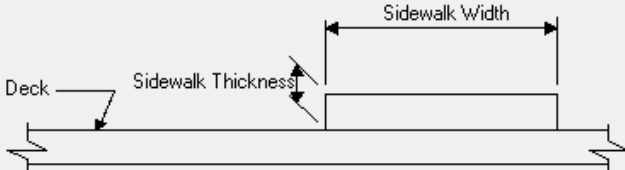
Deck Deck (Cont'd) Parapet Median Railing Generic Sidewalk Lane Position Striped Lanes Wearing Surface

Name	Load Case	Measure To	Edge of Deck Dist. Measured From	Distance At Start (ft)	Distance At End (ft)	Front Face Orientation
Pedestrian Barrier	DL2 DC	Back	Left Edge	0.00	0.00	Right
Pedestrian Barrier	DL2 DC	Back	Right Edge	0.00	0.00	Left

New Duplicate Delete

OK Apply Cancel

Structure Typical Section



Deck Deck (Cont'd) Parapet Median Railing Generic Sidewalk Lane Position Striped Lanes Wearing Surface

Width (in)	Thickness (in)	Concrete Material	Load Case	Measure To	Edge of Deck Dist. Measured From	Distance At Start (ft)	Distance At End (ft)	Pedestrian Load (ksf)
72.0000	6.0000	Deck Concrete	DL1 DC	Left	Left Edge	0.00	0.00	
72.0000	6.0000	Deck Concrete	DL1 DC	Right	Right Edge	0.00	0.00	

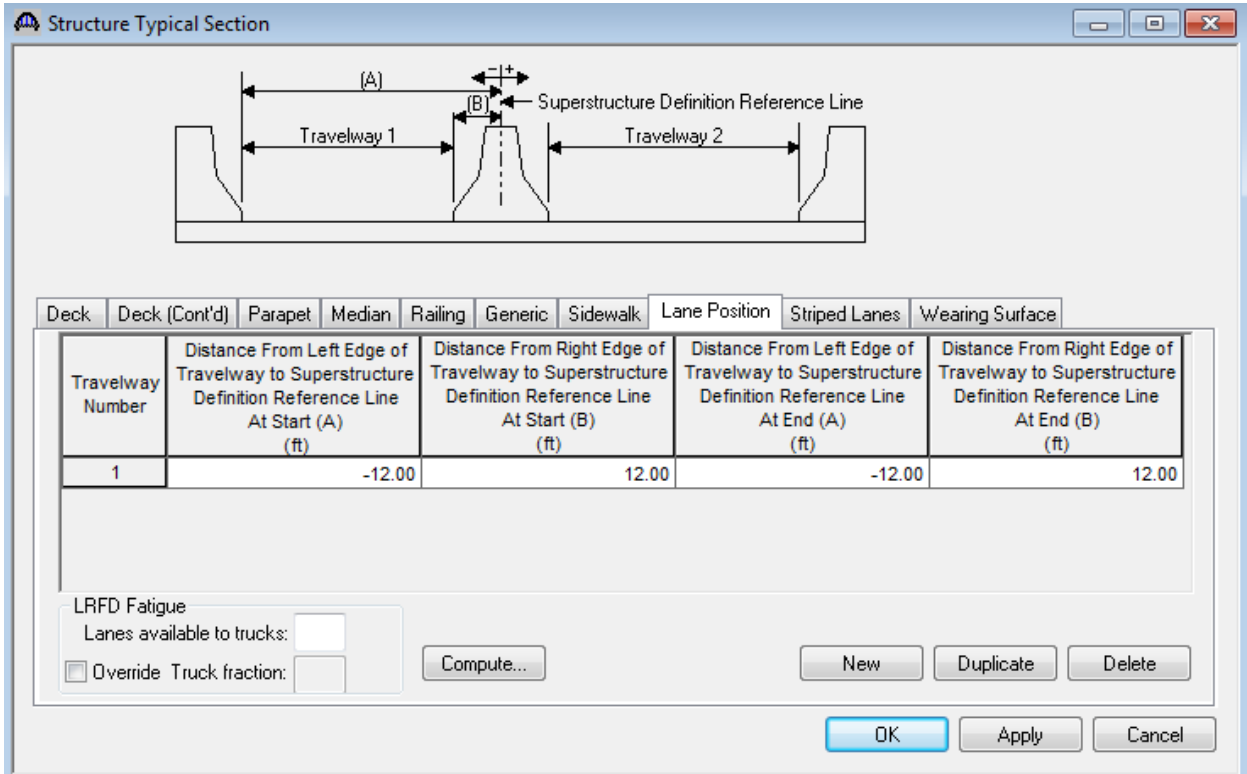
New Duplicate Delete

OK Apply Cancel

PS5 – Void Prestressed Box Beam Example

Lane Positions:

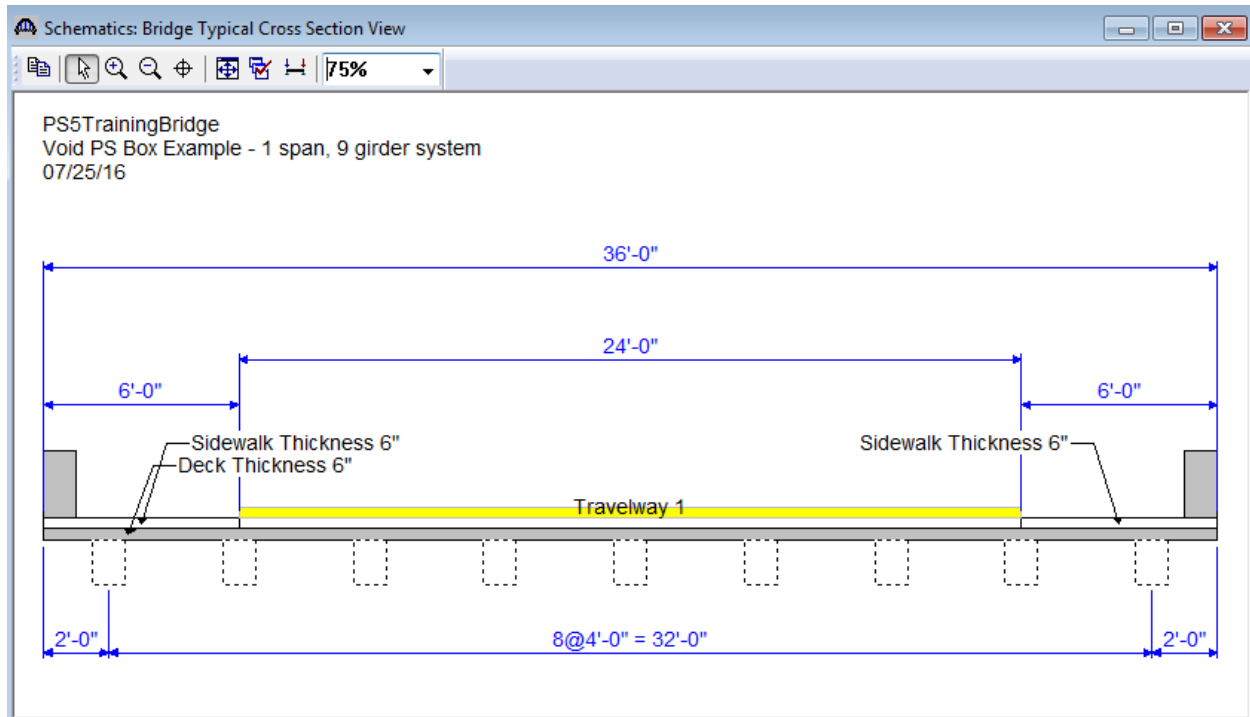
Select the Lane Position tab and use the Compute... button to compute the lane positions. A dialog showing the results of the computation opens. Click Apply to apply the computed values. The Lane Position tab is populated as shown below.



Click Ok to save the data to memory and close the window.

PS5 – Void Prestressed Box Beam Example

The structure typical section schematic can be viewed by selecting “Structure Typical Section” in the Bridge Workspace tree and clicking the “View Schematic” toolbar button.



The beams are displayed as dashed boxes since we have not defined the beams yet.

PS5 – Void Prestressed Box Beam Example

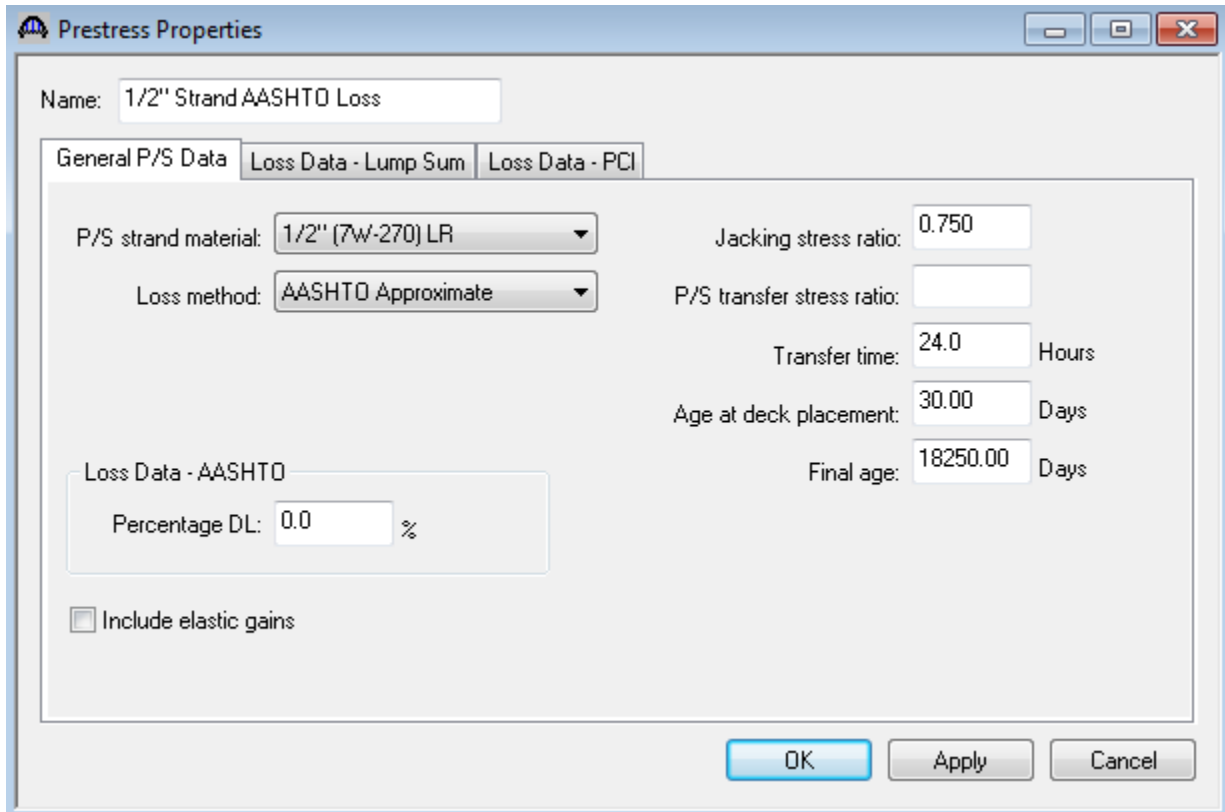
Now define a Stress Limit. A Stress Limit defines the allowable concrete stresses for a given concrete material. Double click on the Stress Limits tree item to open the window. Select the “PS 6.5 ksi” concrete material. Default values for the allowable stresses will be computed based on this concrete and the AASHTO Specifications. A default value for the final allowable slab compression is not computed since the deck concrete is typically different from the concrete used in the beam.

	LFD	LRFD
Initial allowable compression:	2.700 ksi	2.700 ksi
Initial allowable tension:	0.200 ksi	0.200 ksi
Final allowable compression:	3.900 ksi	3.900 ksi
Final allowable tension:	0.484 ksi	0.484 ksi
Final allowable DL compression:	2.600 ksi	2.925 ksi
Final allowable slab compression:	2.700 ksi	2.700 ksi
Final allowable compression: (LL + 1/2(Pe + DL))	2.600 ksi	2.600 ksi

The final allowable tension values are calculated using the Stress Limit Coefficient found on the System Defaults: Bridge Workspace window. This coefficient is dependent on the moderate or severe corrosive condition to which the members are exposed.

PS5 – Void Prestressed Box Beam Example

Double click on the Prestress Properties tree item to open a window in which to define the prestress properties for this structure definition. Define the Prestress Property as shown below. We are using the AASHTO method to compute losses so the “General P/S Data” tab is the only tab that we have to visit. Click Ok to save to memory and close the window.



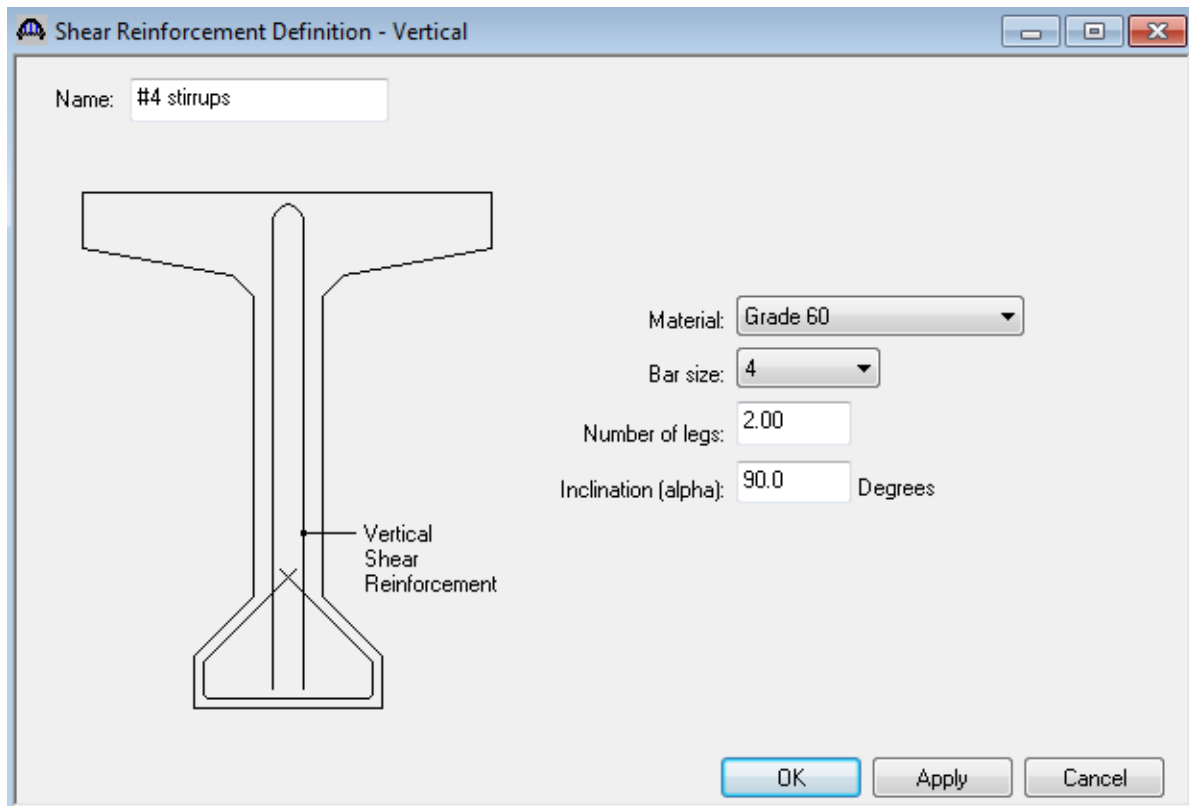
The screenshot shows a software dialog box titled "Prestress Properties". At the top, the "Name" field is set to "1/2\" Strand AASHTO Loss". Below this, there are three tabs: "General P/S Data", "Loss Data - Lump Sum", and "Loss Data - PCI". The "General P/S Data" tab is active. It contains several input fields and a checkbox:

- "P/S strand material": 1/2\" (7W-270) LR
- "Loss method": AASHTO Approximate
- "Jacking stress ratio": 0.750
- "P/S transfer stress ratio": (empty)
- "Transfer time": 24.0 Hours
- "Age at deck placement": 30.00 Days
- "Final age": 18250.00 Days
- "Loss Data - AASHTO" section: "Percentage DL": 0.0 %
- Checkbox: "Include elastic gains" (unchecked)

At the bottom right, there are three buttons: "OK", "Apply", and "Cancel".

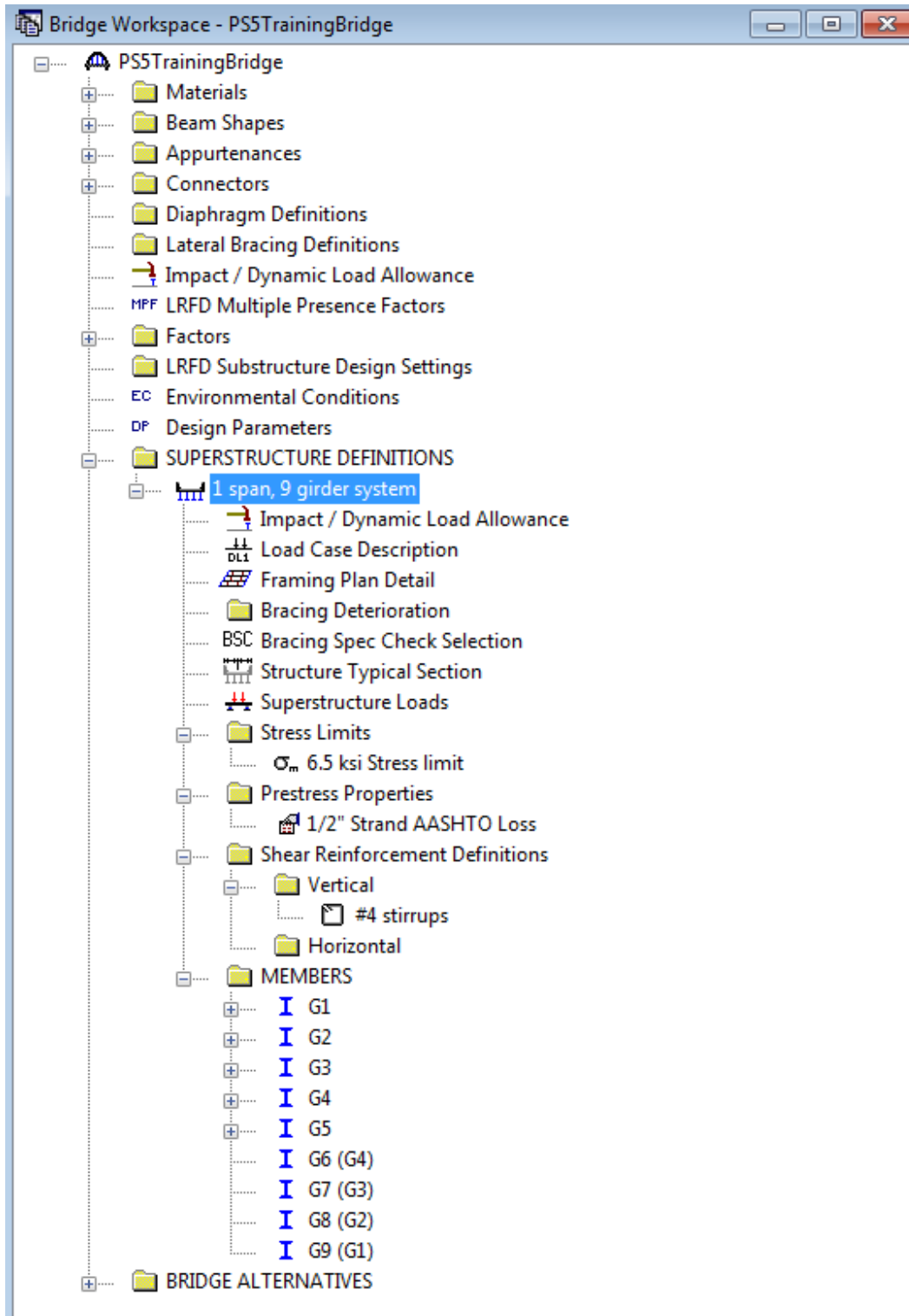
PS5 – Void Prestressed Box Beam Example

Now define the vertical shear reinforcement by double clicking on Vertical (under Shear Reinforcement Definitions in the tree). Define the reinforcement as shown below. Click Ok to save to memory and close the window.



PS5 – Void Prestressed Box Beam Example

A partially expanded Bridge Workspace is shown below.



PS5 – Void Prestressed Box Beam Example

Describing a member:

The member window shows the data that was generated when the structure definition was created. No changes are required at this time. The first Member Alternative that we create will automatically be assigned as the Existing and Current Member alternative for this Member.

Member name: G2 Link with: None

Description:

Existing	Current	Member Alternative Name	Description
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Number of spans: 1

Span No.	Span Length (ft)
1	52.00

OK Apply Cancel

PS5 – Void Prestressed Box Beam Example

Defining a Member Alternative:

Double-click MEMBER ALTERNATIVES in the tree to create a new alternative. The New Member Alternative dialog will open. Select Prestressed (Pretensioned) Concrete for the Material Type and PS Precast Box for the Girder Type.

Click Ok to close the dialog and create a new member alternative.

The Member Alternative Description window will open. Enter the appropriate data as shown below. The Schedule-based Girder property input method is the only input method available for a prestressed concrete beam.

Member Alternative: S11-48 Box Beam

Description Specs Factors Engine Import Control Options

Description:

Material Type: Prestressed (Pretensioned)
Girder Type: PS Precast Box
Default Units: US Customary

Girder property input method
 Schedule based
 Cross-section based

Default rating method:
LFD

Self Load
Load case: Engine Assigned
Additional self load = kip/ft
Additional self load = %

Crack control parameter [Z]
Bottom of beam: kip/in

Exposure factor
Bottom of beam:

OK Apply Cancel

PS5 – Void Prestressed Box Beam Example

Next describe the beam by double clicking on Beam Details in the tree. The beam shape must be selected in this window prior to using the Compute from Typical Section button in the Live Load Distribution Factors window. So far we have identified the member alternative as being a prestressed box but we have not yet defined if it is a spread box or an adjacent box. The calculation of the live load distribution factors is dependent on the boxes being spread or adjacent. Once we select the beam shape in the Beam Details window, BrR will be able to determine if the boxes are spread or adjacent based on the box width and the girder spacing entered earlier. The Beam Details windows with the appropriate data are shown below.

The screenshot shows a software window titled "Beam Details" with three tabs: "Span Detail", "Stress Limit Ranges", and "Slab Interface". The "Span Detail" tab is active and contains a table with the following data:

Span Number	Beam Shape	Girder Material	Prestress Properties	Use Creep	n	Beam Projection	
						Left End (in)	Right End (in)
1	SII-48	PS 6.5 ksi	1/2" Strand AASHTO Loss	No		7.0000	7.0000

At the bottom of the window are three buttons: "OK", "Apply", and "Cancel".

PS5 – Void Prestressed Box Beam Example

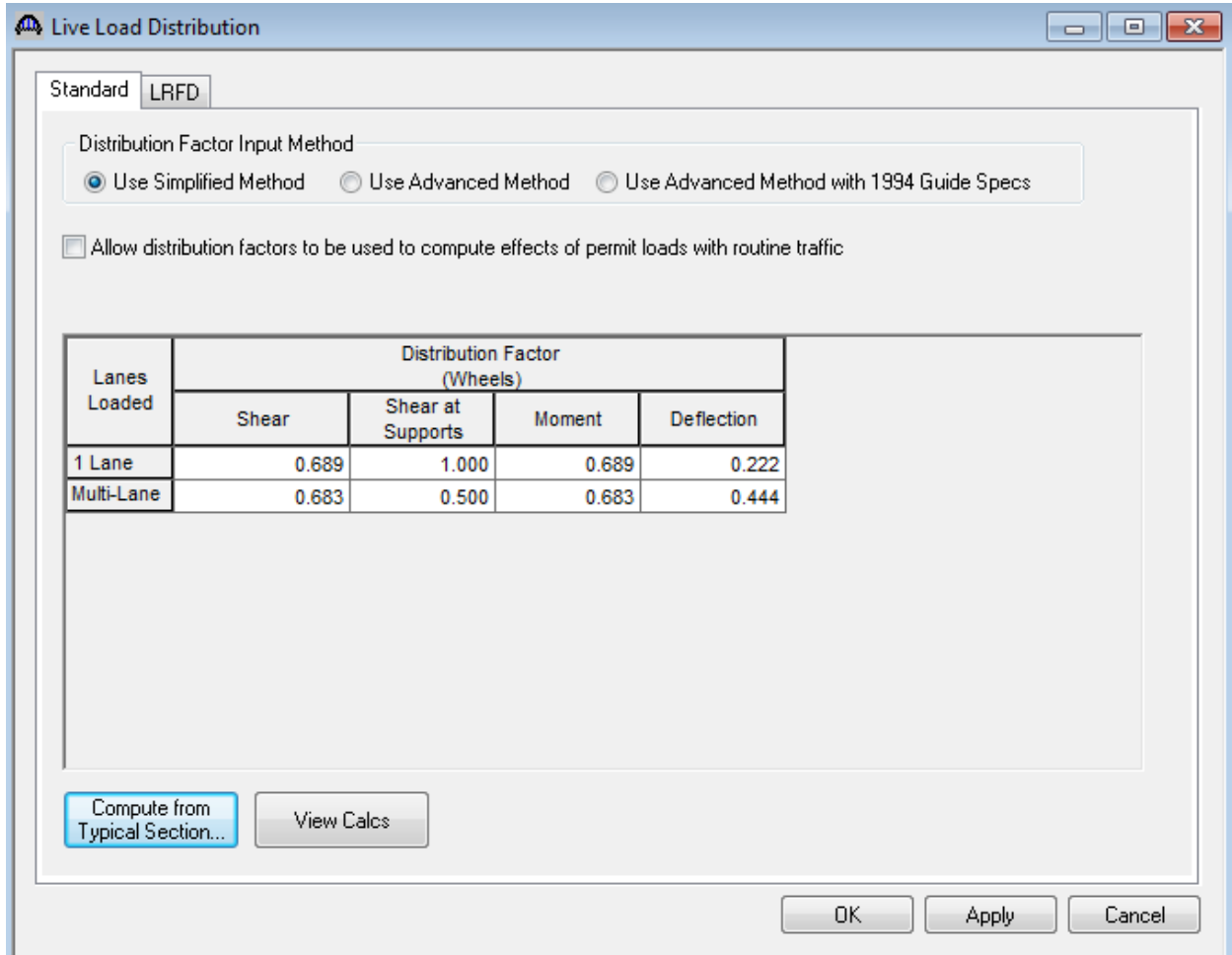
Note that Stress Limit Ranges are defined over the entire length of the precast beam, including the projections of the beam past the centerline of bearing which were entered on the Span Detail tab.

Span Number	Name	Start Distance (ft)	Length (ft)	End Distance (ft)
1	6.5 ksi Stress limit	0.00	53.17	53.17

The defaults on the Slab Interface tab are acceptable. Click Ok to save the Beam Details data to memory and close the window.

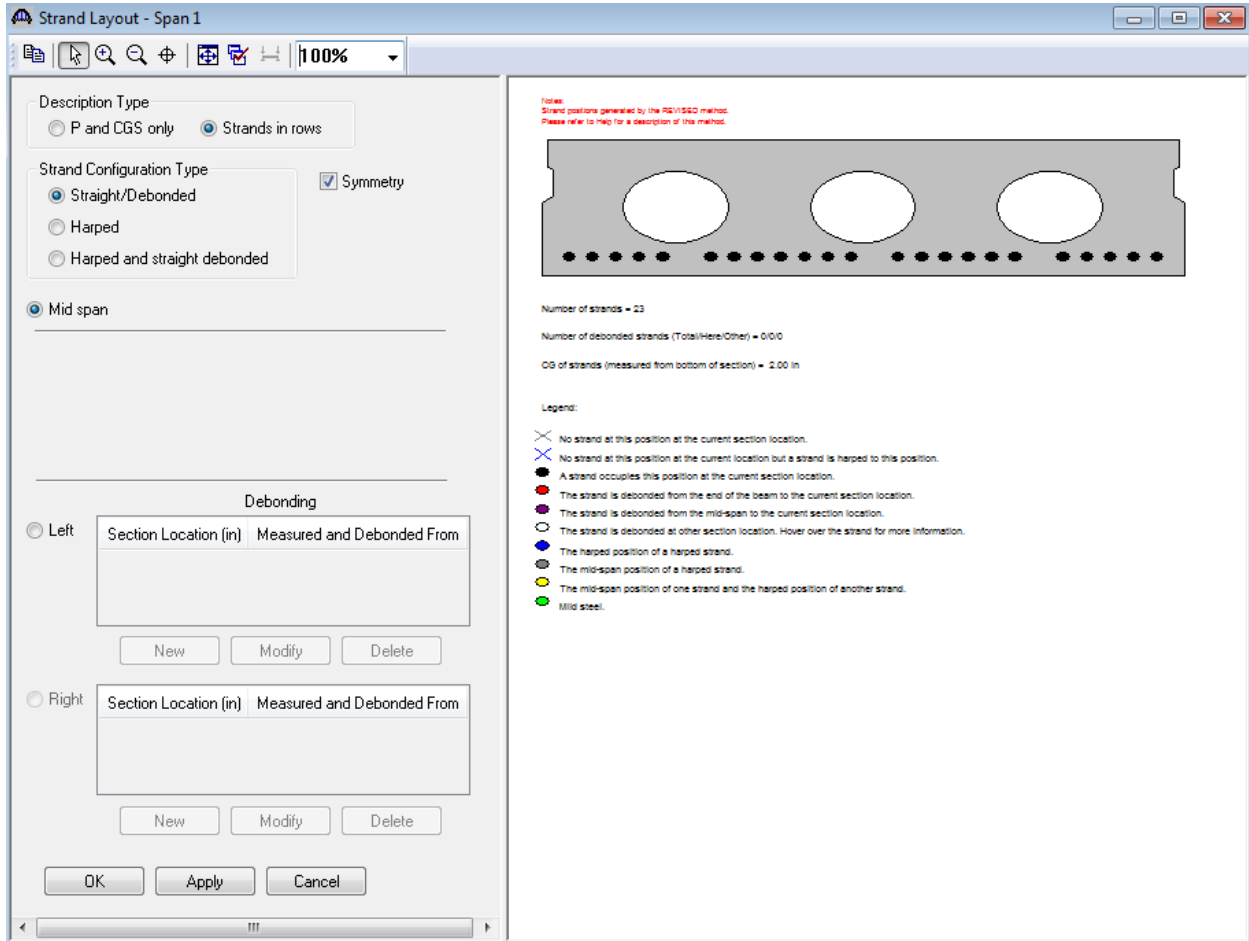
PS5 – Void Prestressed Box Beam Example

Open the Live Load Distribution window. On the Standard tab click on the Compute from Typical Section button to populate the LFD live load distribution factors based on the Structure Typical Section. BrR/BrD will compute the distribution factors based on the girder type, girder spacing, deck geometry and lane positions as per the AASHTO Standard Specifications for Highway Bridges.



PS5 – Void Prestressed Box Beam Example

Expand the Bridge Workspace tree under Strand Layout and open the Span 1 window. Select the Description Type as “Strands in Rows” and the Strand Configuration Type as “Straight/Debonded”. Enter the following data to describe the prestress strand configuration. There is no debonding to describe for this beam.



Click Ok to save the data to memory and close the window.

PS5 – Void Prestressed Box Beam Example

Next open the Deck Profile and enter the data describing the structural properties of the deck. The window is shown below.

The screenshot shows a software window titled "Deck Profile". At the top, there is a "Type:" field containing "PS Precast Box". Below this, there are two tabs: "Deck Concrete" (which is selected) and "Reinforcement". The main area of the window contains a table with the following data:

Material	Support Number	Start Distance (ft)	Length (ft)	End Distance (ft)	Structural Thickness (in)	Start Effective Flange Width (Std) (in)	End Effective Flange Width (Std) (in)	Start Effective Flange Width (LRFD) (in)	End Effective Flange Width (LRFD) (in)	n
Deck Concrete	1	0.00	52.00	52.00	6.0000	48.0000	48.0000	48.0000	48.0000	

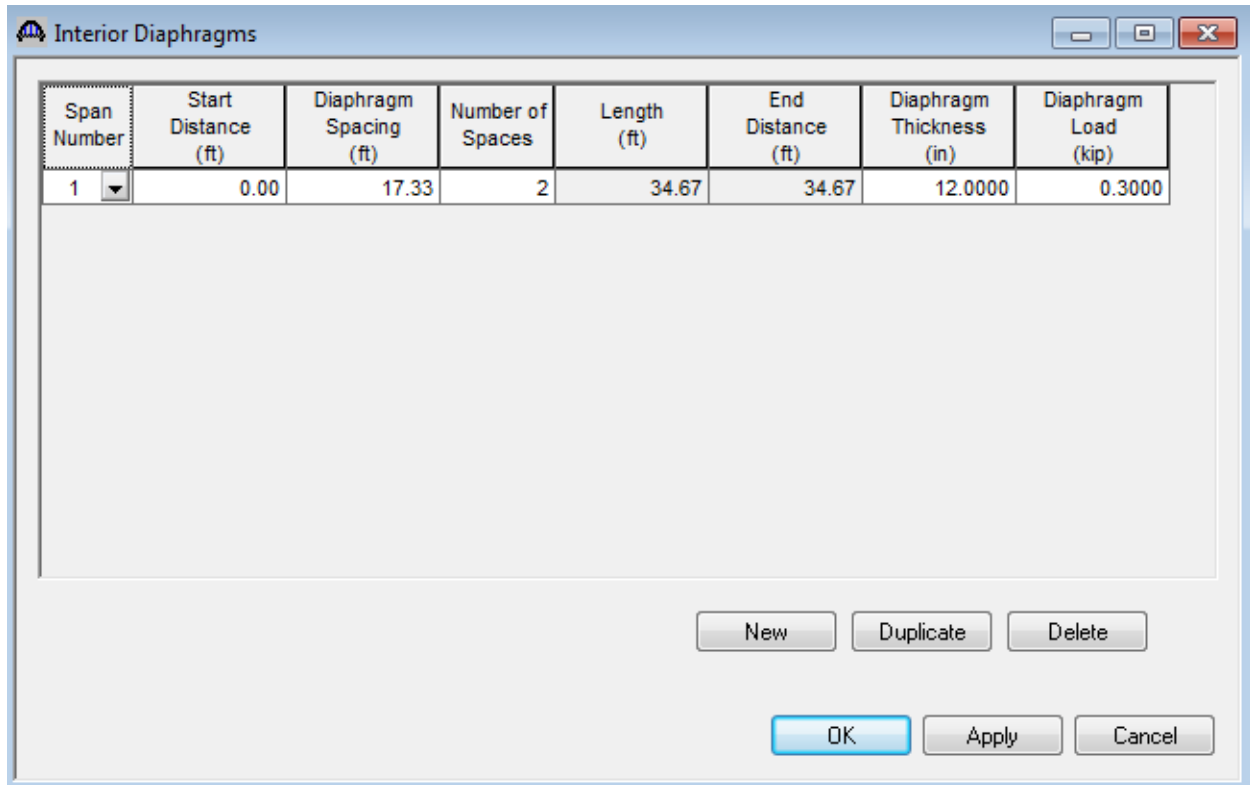
Below the table, there is a "Compute from Typical Section..." button. At the bottom right, there are buttons for "New", "Duplicate", "Delete", "OK", "Apply", and "Cancel".

No reinforcement is described.

There is no haunch profile to define either.

PS5 – Void Prestressed Box Beam Example

The internal diaphragms for this box member are entered as described below.

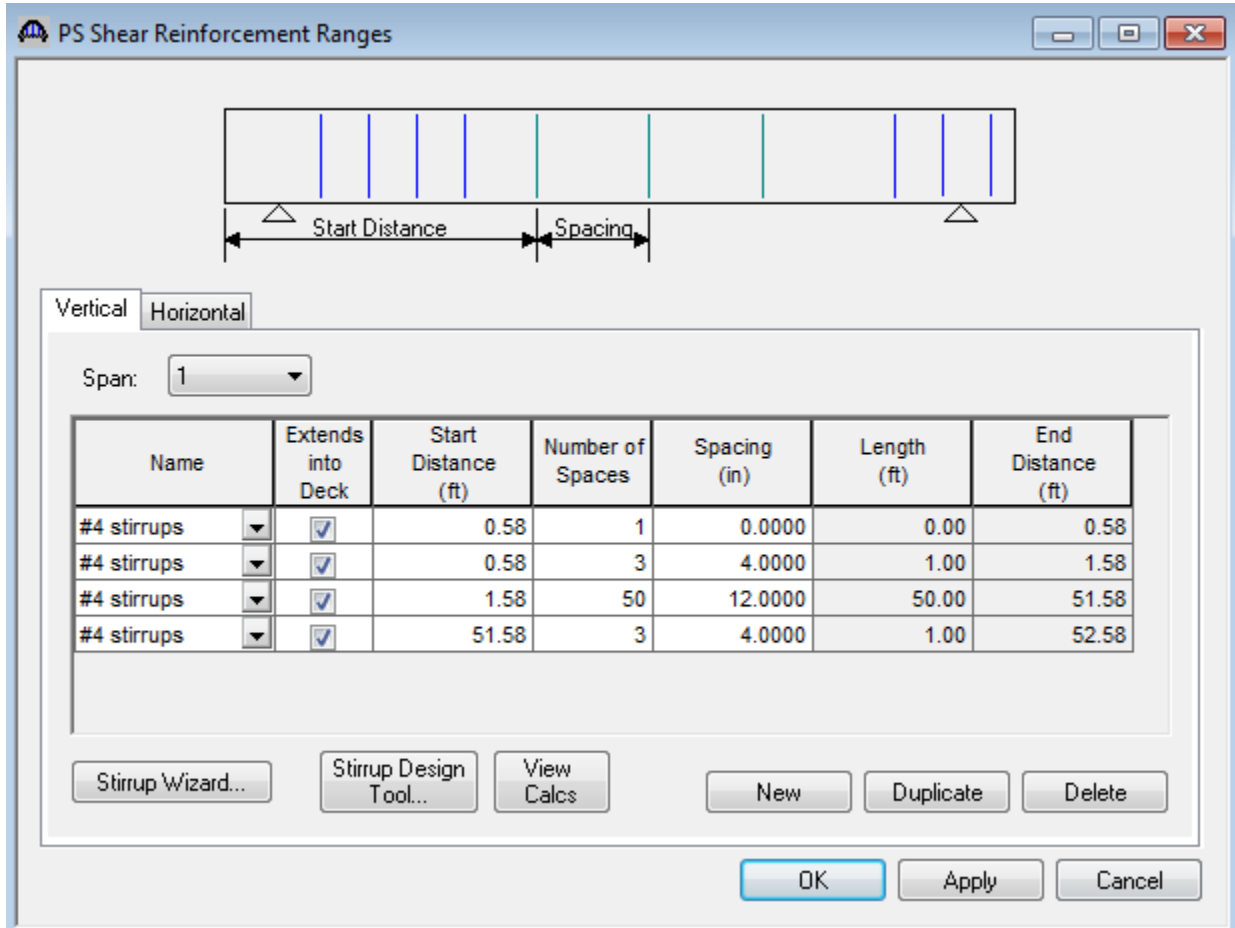


The screenshot shows a software dialog box titled "Interior Diaphragms". It contains a table with the following columns: Span Number, Start Distance (ft), Diaphragm Spacing (ft), Number of Spaces, Length (ft), End Distance (ft), Diaphragm Thickness (in), and Diaphragm Load (kip). The table has one row with the following values: Span Number 1, Start Distance 0.00, Diaphragm Spacing 17.33, Number of Spaces 2, Length 34.67, End Distance 34.67, Diaphragm Thickness 12.0000, and Diaphragm Load 0.3000. Below the table are buttons for "New", "Duplicate", "Delete", "OK", "Apply", and "Cancel".

Span Number	Start Distance (ft)	Diaphragm Spacing (ft)	Number of Spaces	Length (ft)	End Distance (ft)	Diaphragm Thickness (in)	Diaphragm Load (kip)
1	0.00	17.33	2	34.67	34.67	12.0000	0.3000

PS5 – Void Prestressed Box Beam Example

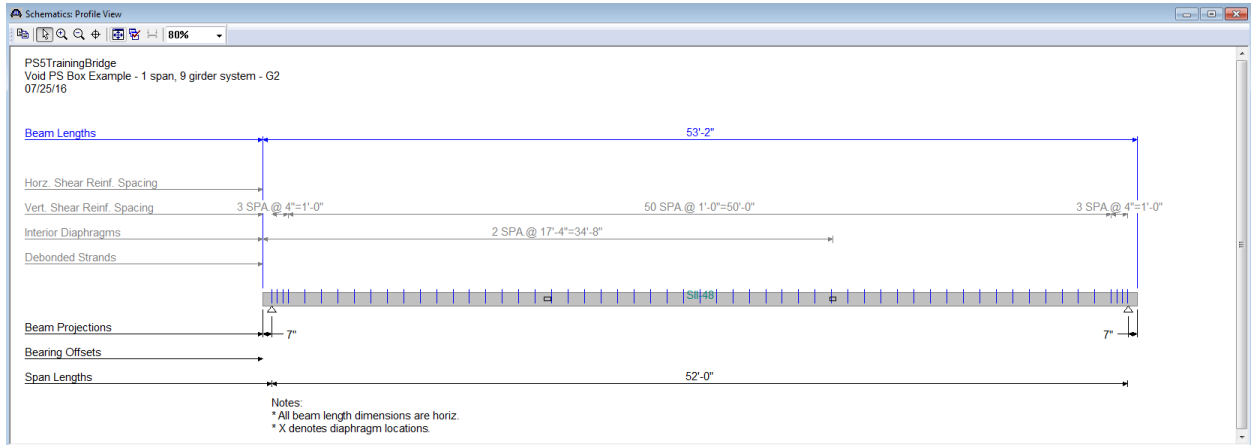
The Shear Reinforcement Ranges are entered as described below. The vertical shear reinforcement is defined as extending into the deck on this tab. This indicates composite action between the beam and the deck. Data does not have to be entered on the Horizontal tab to indicate composite action since we have defined that by extending the vertical bars into deck.



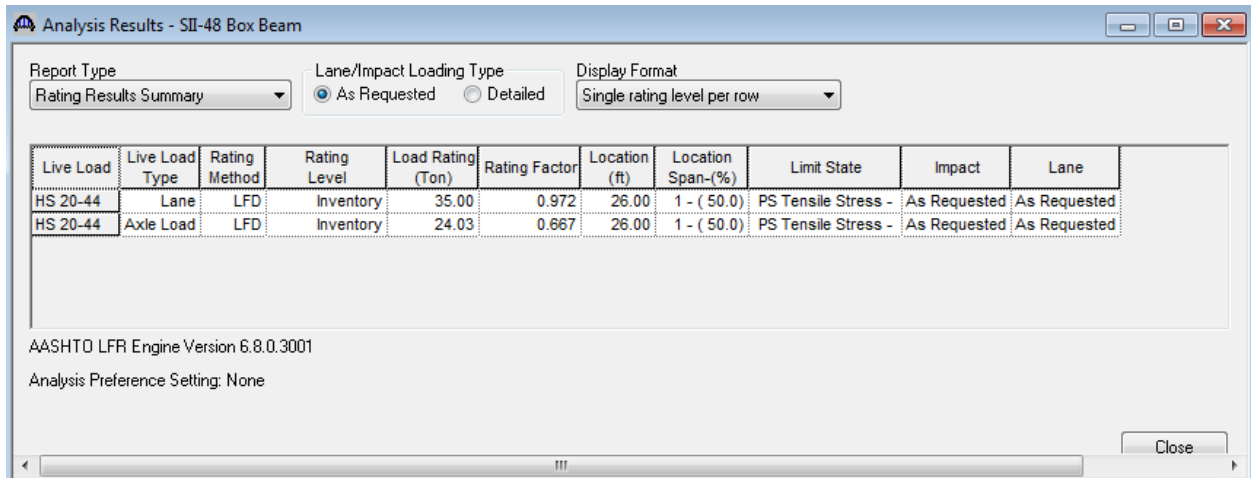
The description of an interior beam for this structure definition is complete.

PS5 – Void Prestressed Box Beam Example

The girder elevation can be displayed by selecting the “View schematic” toolbar button while the name of the member alternative is selected in the Bridge Workspace tree.

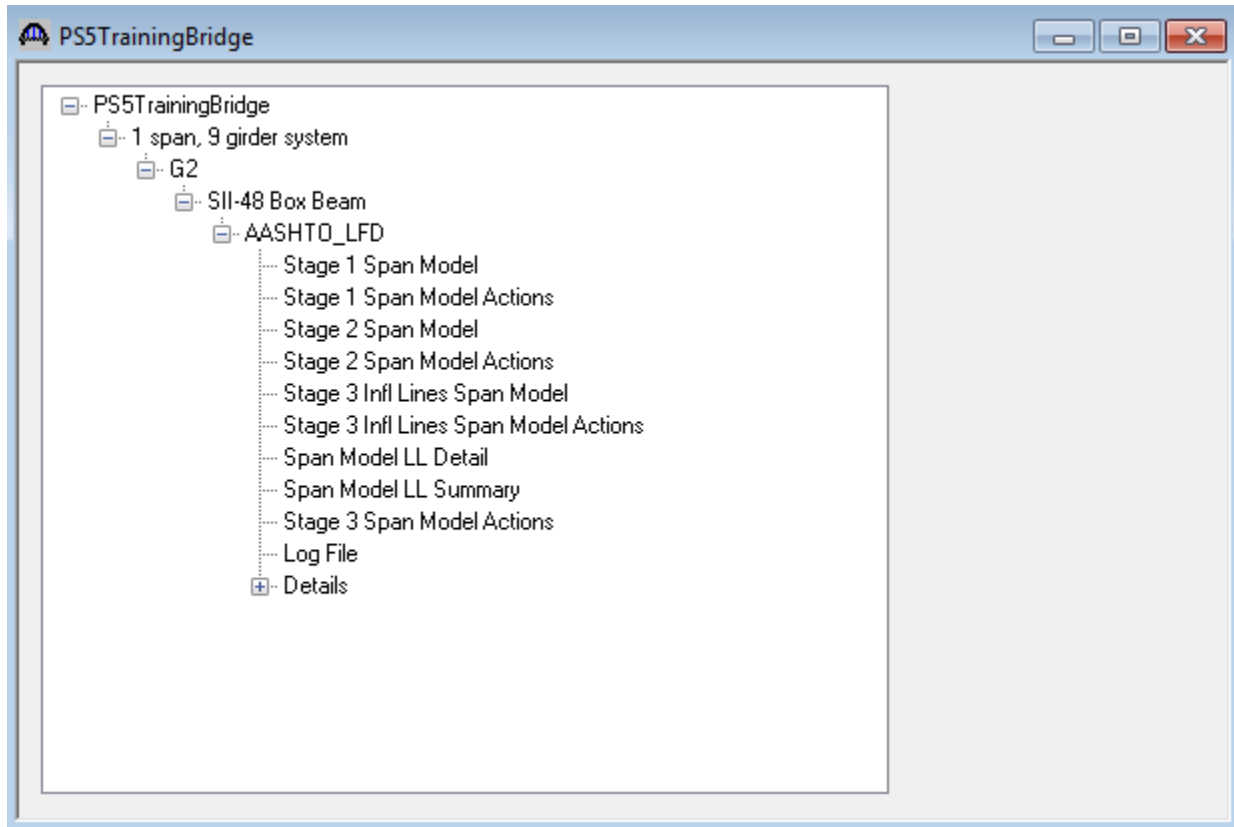


The results for rating an HS20 vehicle using Load Factor Design are shown below:



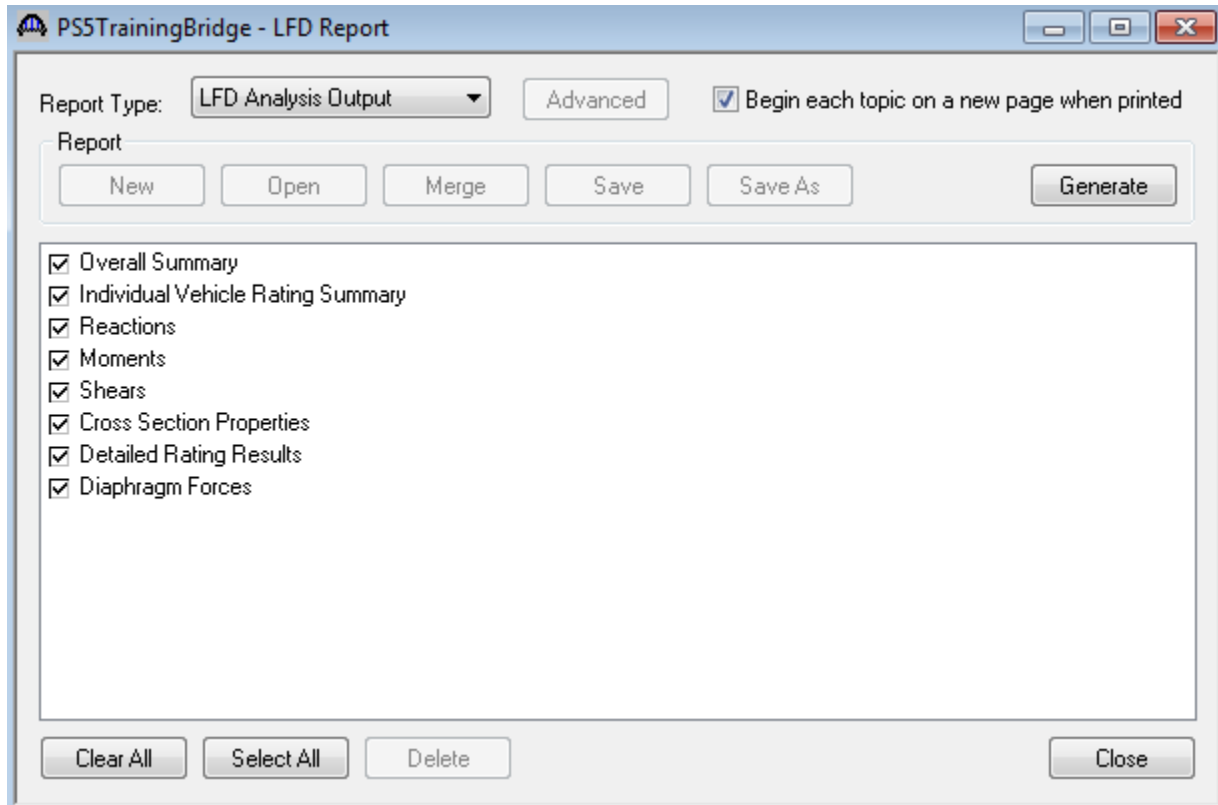
PS5 – Void Prestressed Box Beam Example

The analysis output files can be viewed by selecting the “View analysis output” button on the toolbar. The following window will open.



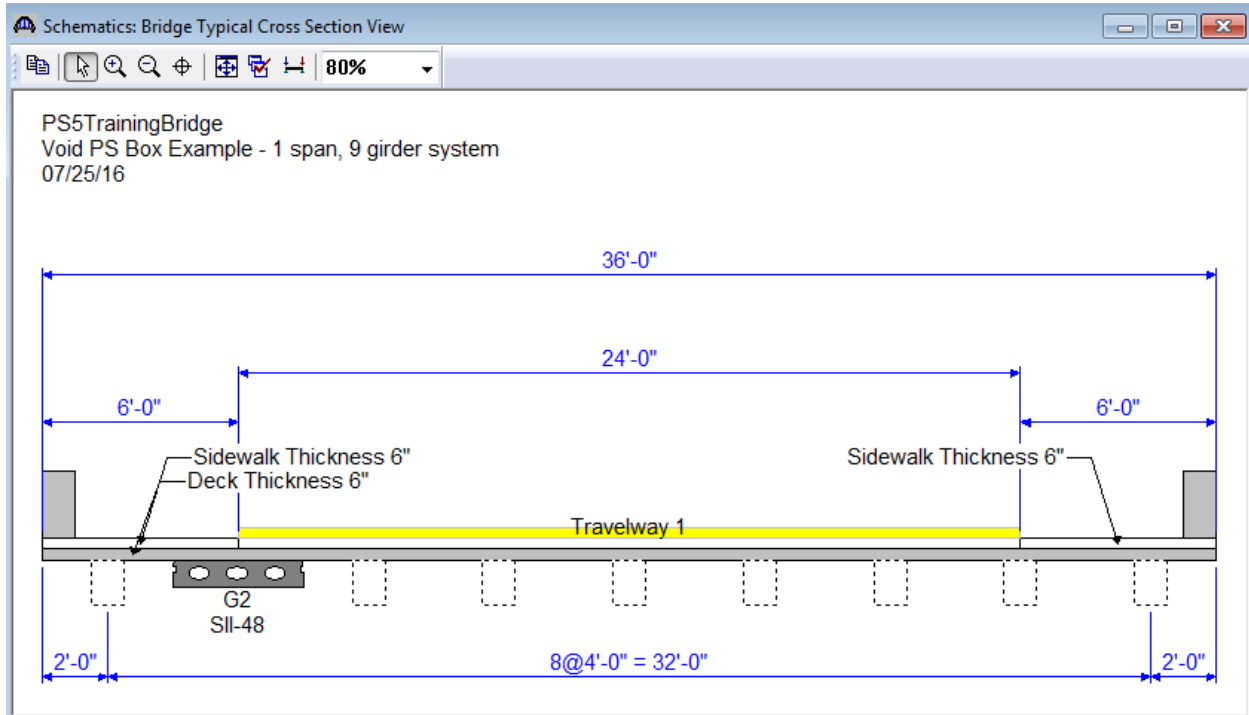
PS5 – Void Prestressed Box Beam Example

A summarized report of the output can be generated by selecting the “Report Tool” button from the toolbar. Select “LFD Analysis Output” in the Report Type box. You can specify which output you want the report to contain. Selecting “Generate” will open Internet Explorer and display the generated report. The report can be printed from Internet Explorer.



PS5 – Void Prestressed Box Beam Example

The following schematic is displayed if we select “View schematic” while the Structure Typical Section is selected in the Bridge Workspace tree.



Member G2 is the only member that has a member alternative defined. We can easily copy this member alternative to Member G1 to minimize the amount of data entry for this structure. Select “SII-48 Box Beam” under Member G2 in the Bridge Workspace tree and click the “Copy” button on the toolbar. Select “MEMBER ALTERNATIVES” under Member G1 and click the “Paste” button. Now Member G1 has a member alternative named “Copy of SII-48 Box Beam”. Since G1 is an exterior girder and G2 is an interior girder, there are a few windows under G1 that must be revisited to modify the data to represent an exterior girder. The Live Load Distribution Factors window should be opened and appropriate distribution factors entered for this exterior girder. The Deck Profile and Haunch Profile windows should also be modified to represent the exterior girder.

Use the copy function to copy the member alternative for Member G2 to Members G3, G4, and G5. Adjust the live load distribution factors as necessary for Members G3, G4, and G5. Depending on the arrangement of the lane positions and the girders, the simple beam distribution factors for the interior girders may differ. It is a good idea to recalculate the distribution factors for copied member alternatives. We now have half of the girders in the structure defined.

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We can use the Link function in BrR to Link the remaining girders in the structure to the members we have defined. If two members are linked, they share the same definition and any revisions to one member affects the other member. If there are any differences between two members, then they should not be linked with one another. If the applied loads acting on the two members are different (due to different tributary widths, different arrangements of parapets, medians, sidewalks, and railings, and different lane positions), then they should not be linked with one another. All calculations are based on the properties and loads of the original girder. Open the Member G6 window and select “G4” in the Link with box. A warning message will appear to remind you that both members must share the exact same definition if they are to be linked. Click “Continue” to link the two members. Click Ok to save the data to memory and close the window.

Member name: Link with:

Description:

Existing	Current	Member Alternative Name	Description
<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	Copy of SI-48 Box Beam	

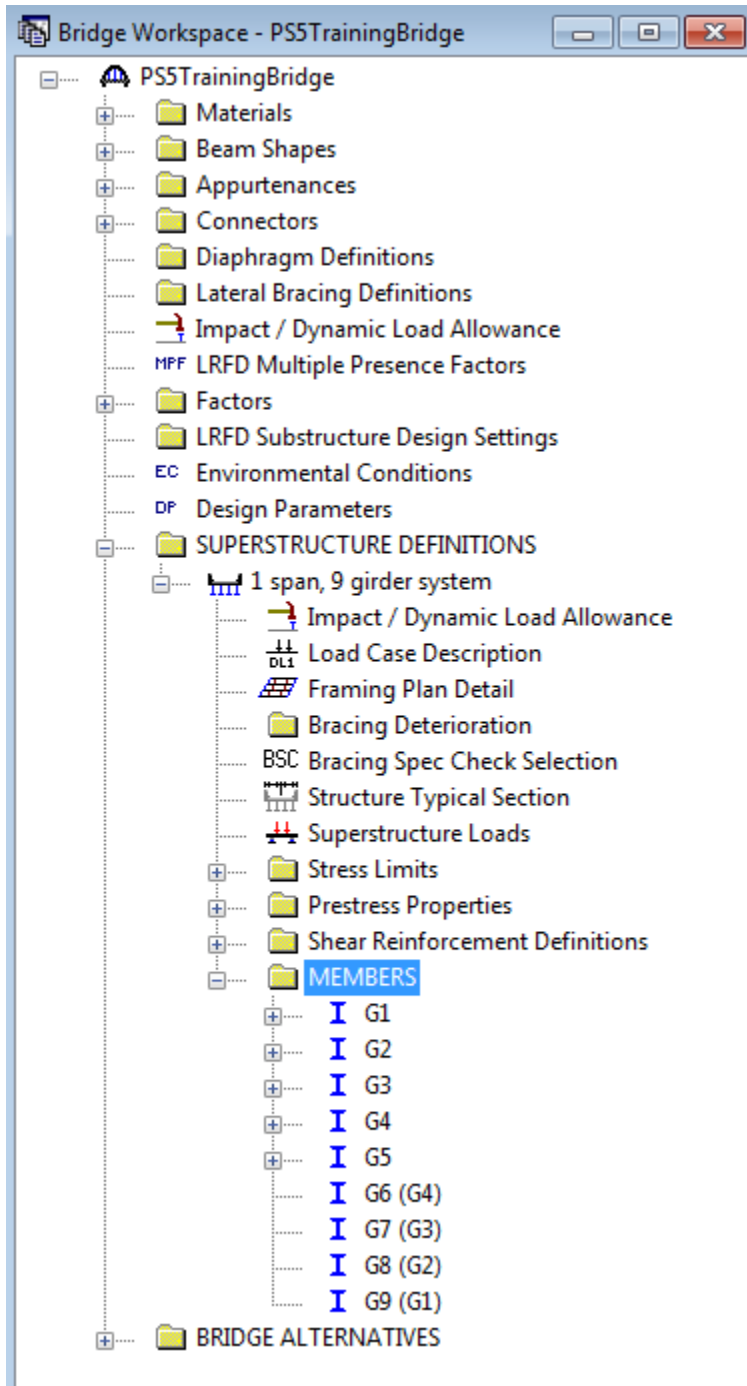
Number of spans:

Span No.	Span Length (ft)
1	52.00

Member G6 now shares the same definition as Member G4. Use this procedure to link Member G7 with G3, Member G8 with G2, and Member G9 with G1.

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The following Bridge Workspace and Structure Typical Section Schematic will result.



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